Predicting equations of main factors affecting regional climate in the "Three-North" Protective Forest Area

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Abstract The relationship between the change of forest resources and climatic factor in the "Three-North" region of China were studied in this paper. The predicting equations of climatic factor (dependent variable) with regional independent variable (longitude, latitude and altitude) and stand independent variable (forest coverage rate), were developed by extensively using the linear and nonlinear regression methods. With these models, we can calculate the ecological benefit of Shelter-belt forest.
Key words: Three-North protective forest, Regional independent variable, Stand independent variable, Regression equation, Ecological benefit

Introduction

In order to solve the serious ecological problem we faced and improve the phenomenon of land desertification in the north area of China. China has begun to construct the Three-North Protective Forest System since 1978. With the hard work of twenty years, it is told "The greatest ecological project of the world" and "The green great wall". Although the country invested lots of capital to build the Three-North shelter-forest system through many ways such as Three-North special investment, finance appropriate funds, financial loans and take out funds for bring up trees, but lack of funds was a very seriously problem during the process. So it is necessary to levy expenses of bring up ecological resources from the units and departments which benefit from the protective forest, and give some compensate to the ecological benefits bring from the protective forest. In this paper, the relationship between the changes of forest resource and climatic factors in Three-North district was studied, and the regression equations of climatic factors and regional factors were developed. The results can provide some scientific bases to calculate the ecological benefits of protective forest.

Materials and methods

Data collection

The data used in this paper was collected from more than one hundred counties of Heilongjiang, Jilin, Liaoning and Inner Mongolia. These areas lay between longitude 122°12'~130°18' E and latitude 43°~50°24' N. The data contains geographic data (longitude, latitude, altitude) and forest coverage rate and climatic factors (mean annual temperature, annual precipitation, mean annual wind speed, annual evaporation, annual accumulated temperature for ≥ 10 °C) of typical years of each county.

Variables

Three types of variables were used.

Dependent variables:

Y_1= mean annual temperature, ℃

Y_2= annual precipitation, mm

Y_3= mean annual wind speed, m/s

Y_4= annual evaporation, mm

Y_5= annual accumulated temperature≥10℃, ℃

Regional independent variables

X_1= longitude (°)

X_2= latitude (°)

X_3= altitude, m

Stand independent variable

X_4= forest coverage rate, %

The mean, maximum, and minimum values of each variable were listed in Table 1

Models

In order to develop the models to express the regression relationship of these variables perfectly, the following methods were used to build the regression models of each variable.

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Table 1. The characteristic values of each variables

Variables	Mean	Minimum	Maximum
Longitude (°)	125.3620	122.200	130.300
Latitude (°)	46.0970	43.000	50.400
Forest coverage rate, %	16.5640	3.400	71.100
Altitude, m	220.5650	81.200	528.500
Mean annual temperature, ℃	3.4663	-0.500	6.000
Annual precipitation, mm	495.6278	344.200	889.000
Mean annual wind speed, m/s	3.7543	1.800	5.200
Annual evaporation, mm	1507.5420	752.500	2083.300
Annual accumulated temperature ≥10℃, ℃	2723.7480	2153.000	3138.800

We choose seven models and calculate the relation coefficient of every dependent variable and each independent variable, and according to these coefficients to make sure of the relationship of dependent variables and independent variables. The calculation results were listed in Table 2

According to the relationship of variables we can build regression models of each dependent variable and every independent variable as follows:

Mean annual temperature:

Y_1=a+bX_1+cX_1^2+dX_2+eX_3+fX_3^2+gX_4+ hX_4^2+iX_4^3

Annual precipitation:

Y_2=a+bX_1+cX_1^2+dX_2+eX_2^2+fX_2^3+gX_3+hX_3^2+iX_4+jX_4^2

Mean annual wind speed:

Y_3=a+bX_1+cX_1^2+dX_1^3+eX_2+fX_2^2+gX_2^3+hX_3+I*exp(jX_4)

Annual evaporation:

Y_4=a+bX_1+cX_1^2+dX_1^3+eX_2+fX_2^2+gX_3+ hX_3^2+iX_4+jX_4^2

Annual accumulated temperature for ≥10℃:

Y_5=a+bX_1+cX_1^2+dX_1^3+e*exp(fX_2)+gX_3+hX_3^2+iX_3^3+ J*exp(kX_4)

Where: a, b, c, d, e, f, g, h, i, j and k are the parameters to be estimated.

Estimate and test the parameters in these models, the result is list in Table 3.

Table 2. Regression equation and relation coefficient of every dependent variables and each independent variables

Dependent variables (Y)	Independent variables (X)	Regression equations	Relation coefficient
Mean annual temperature	Longitude	Y=a+bx+cx^2	0.608276
	Latitude	Y=a+bx	0.956242
	Altitude	Y=a+bx+cx^2	0.341027
	Forest coverage rate	Y=a+bx+cx^2+dx^3	0.700556
Annual precipitation	Longitude	Y=a+bx+cx^2	0.641864
	Latitude	Y=a+bx+cx^2+dx^3	0.591687
	Altitude	Y=a+bx+cx^2	0.652937
	Forest coverage rate	Y=a+bx+cx^2	0.685769
Mean annual wind speed	Longitude	Y=a+bx+cx^2+dx^3	0.741650
	Latitude	Y=a+bx+cx^2+dx^3	0.727203
	Altitude	Y=a+bx	0.441814
	Forest coverage rate	Y=a+b*exp(cx)	0.770203
Annual evaporation	Longitude	Y=a+bx+cx^2+dx^3	0.530595
	Latitude	Y=a+bx+cx^2	0.588132
	Altitude	Y=a+bx+cx^2	0.473286
	Forest coverage rate	Y=a+bx+cx^2	0.637882
Annual accumulated temperature≥10℃	Longitude	Y=a+bx+cx^2+dx^3	0.649570
	Latitude	Y=a+b*exp(cx)	0.906724
	Altitude	Y=a+bx+cx^2+dx^3	0.518169
	Forest coverage rate	Y=a+b*exp(cx)	0.725672

Table 3. Estimated value of parameters

parameters	Dependent variables				
	Y_1	Y_2	Y_3	Y_4	Y_5
a	965.3284	-10207.1	-34632.7	3055230	1028.517
b	-14.4886	808.2876	889.8219	-72197.5	-608.601
c	0.056858	-3.12181	-7.01699	568.5245	10.55819
d	-0.810199	-2655.69	0.018437	-1.49322	-0.044130
e	0.010425	56.50568	-192.044	252.9407	-0.001737
f	-0.000201	-0.402962	4.148953	-3.37242	0.262950
g	-0.020214	1.642257	-0.029846	-0.943575	-6.71816
h	0.00006	-0.002303	-0.016956	0.001048	0.021269
i	0	2.863701	42.1575	-11.5772	-0.000020
j		-0.035938	-2.19089	0.140510	-0.000352
k					0.141712
Correlation Coefficient	0.95850665	0.67365259	0.838211478	0.709142781	0.915010736

Form these statistical results, we can find that the regression relationship of these independent variables were very significantly. So we can develop regression models as follows:

(1) Mean annual temperature (Y_1):

$$Y_1=965.3284-14.4886X_1+0.056858X_1^2-0.810199X_2+0.010425X_3-0.000201X_3^2-0.020214X_4+0.00006X_4^2$$

(2) Annual precipitation (Y_2):

$$Y_2=-10207.1+808.2876X_1-3.12181X_1^2-2655.69X_2+56.50568X_2^2-0.402962X_2^3+1.642257X_3-0.002303X_3^2+2.863701*374.789X_4-0.035938X_4^2$$

(3) Mean annual wind speed (Y_3):

$$Y_3=-34632.7+889.8219X_1-7.01699X_1^2+0.018437X_1^3-192.044X_2+4.148953X_2^2-0.029846X_2^3-0.016956X_3+42.1575*\exp(-2.19089X_4)$$

(4) Annual evaporation (Y_4):

$$Y_4=3055230-72197.5X_1+568.5245X_1^2-1.49322X_1^3+252.9407X_2-3.37242X_2^2-0.943575X_3+0.001048X_3^2-11.5772X_4+0.140510X_4^2$$

(5) Annual accumulated temperature≥10℃ (Y_5):

$$Y_5=1028.517-608.601X_1+10.55819X_1^2-0.04413X_1^3-0.001737*\exp(0.26295X_2)-6.71816X_3+0.021269X_3^2-0.00002X_3^3-0.000352*\exp(0.141712*X_4)$$

The relationship between observed value and estimated value of each dependent variables can be expressed by Fig.1~5.

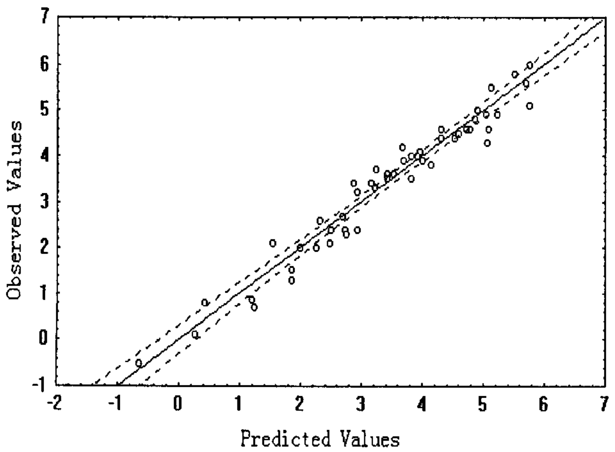

Fig. 1. Observed value and predicted value relationship of mean annual temperature

Conclusion

According to these models we can find that:

(1) The relationships between the mean annual temperature and longitude, latitude, altitude or forest coverage rate are negative correlation, but the affection of longitude, latitude or altitude to mean annual temperature is larger than that of forest coverage rate.

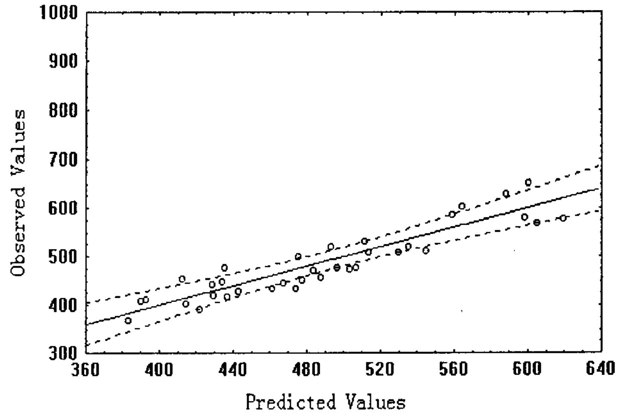

Fig. 2. Observed value and predicted value relationship of annual precipitation

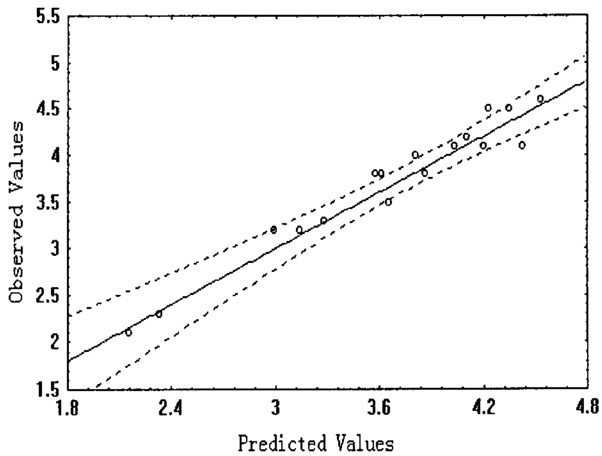

Fig. 3. Observed value and predicted value relationship of mean annual wind speed

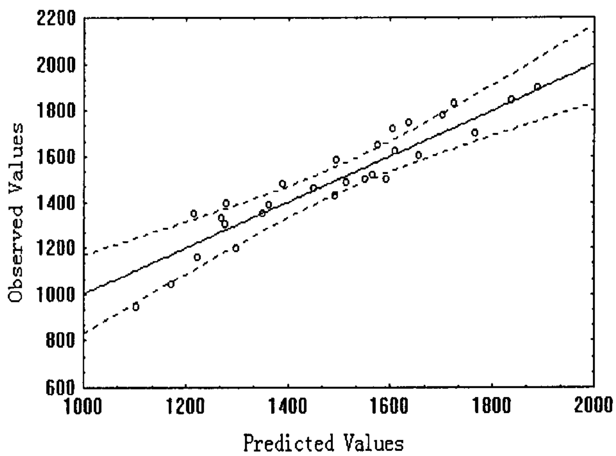

Fig. 4. Observed value and predicted value relationship of annual evaporation

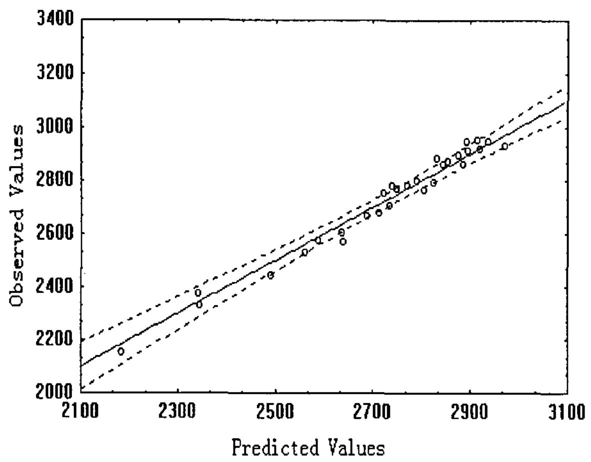

Fig. 5. observed value and predicted value relationship of annual accumulated temperature≥10℃

(2) The relationships between annual precipitation and longitude, altitude or forest coverage rate are positive correlation. The relationship between the annual precipitation and latitude is negative correlation. These four factors have obviously affection to annual precipitation.

(3) The mean annual wind speed and these four factors are all negative correlation. The affection of forest coverage rate to mean annual wind speed is the largest.

(4) The annual evaporation and longitude or latitude are positive correlation. The annual evaporation has negative correlation with altitude or forest coverage rate. The affection of forest coverage rate to annual amount of evaporation is the largest.

(5) The relationships between annual ≥10℃ accumulated temperature and these four factors are negative correlation. The affection of the first three factors is larger than that of forest coverage rate.

From the relationships of factors we can conclude that:

The increase of forest coverage rate can cut down the mean annual wind speed of planting area, reduce the damage of wind and sand, and benefit to agriculture. Meanwhile, since the increasing of forest coverage rate can cause the increases of the annual precipitation and annual evaporation, it will cause little affection to water balance.

The increase of forest coverage rate may cause the decreases of mean annual temperature and annual accumulated temperature for≥10℃, which may cause a little negative effect on agriculture.

As what is mentioned above, the change of stand factor (forest coverage rate) affects the regional climatic factors very obviously. The regression equations can be set up depending on the relationships of the regional independent variables, stand independent variables and the climatic factors (dependent variables). Using these models we can calculate the ecological benefit of shelter-belt forests.

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